National Aeronautics and Space Administration

Glenn Research Center
Cleveland, Ohio

Structure Of Flame Balls At Low Lewis-number-2 (STS–107)
Studying Fire in the Sky

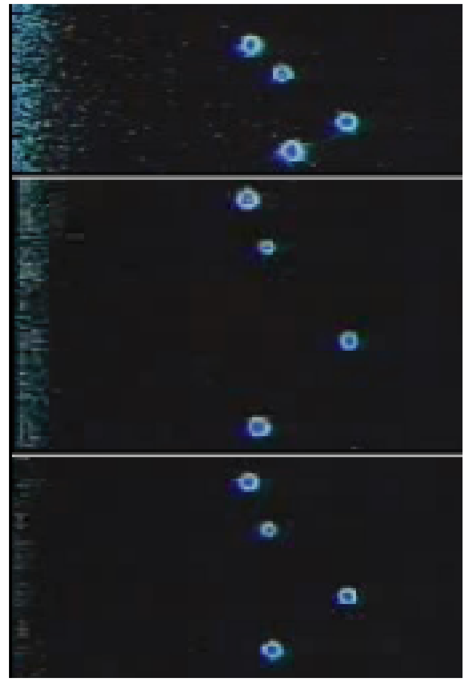
Great Balls of Fire!

For years, scientists have been conducting experiments on flames at low gravity—a condition called "microgravity"—by using drop towers and aircraft flying parabolic trajectories. These experiments have demonstrated a variety of new combustion phenomena that are hidden by the effects of gravity.

One of the more remarkable findings of these experiments was the discovery of "flame balls," which are tiny, stable, stationary, spherically symmetric flames that occur in combustible gas mixtures having low Lewis-numbers, and only in microgravity. Dr. Paul Ronney, a scientist at the University of Southern California, made the discovery in 1984 during a drop tower experiment.

To further study this phenomenom, an experiment called Structure Of Flame Balls At Low Lewis-number (SOFBALL) was performed on two shuttle missions in 1997. It will fly again onboard STS–107.

The Lewis-number part of SOFBALL is a measure of the rate of diffusion of fuel into the flame ball relative to rate of diffusion of heat away from the flame ball. Hydrogen and methane are the only fuels that provide low enough Lewis-numbers to produce stable flame balls, and even then only for very weak, barely flammable mixtures. Nevertheless, these flame balls give scientists the chance to test combustion models in an ideal environment.



Flame balls seem to shine bright as stars, but only because they are observed in the dark by cameras with image intensifiers. Under normal lighting in a space module, the flame balls would be invisible—to the eye and to fire detectors—and, consequently, potentially hazardous.

Science Objectives

The goals of the SOFBALL–2 experiment are to

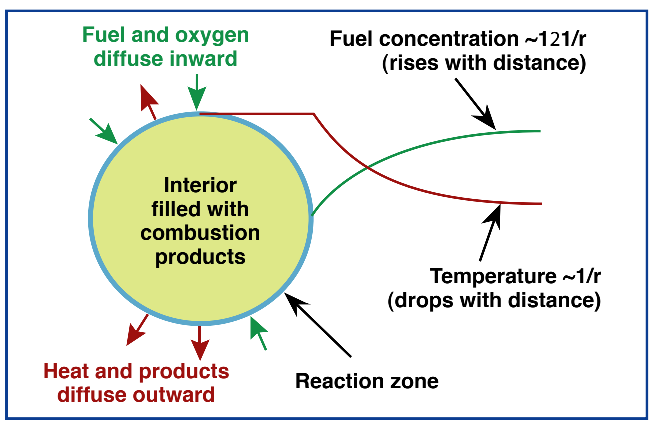
- Improve our understanding of the flame balls phenomenon
- Determine the conditions under which flame balls can exist
- Test predictions of flame ball lifetimes
- Acquire more precise data for critical model comparison

Application of SOFBALL Results

- Improved design of lean-burning car engines
- Improved detection of fire and explosion hazards in mine shafts, oil refineries, and chemical plants
- Improved safety aboard spacecraft from the hazards presented by long-lived flame balls

SOFBALL–2 Science

SOFBALL burns extremely lean fuel-air mixtures that are near the lower limit of combustion. The mixtures are ignited by an electrical spark. Because the mixture is lean and has a low Lewis-number, the flame does not spread across the mixture. Instead, the flame forms a spherical shell filled with combustion products and supported by fuel and oxygen diffusing inward while heat and combustion products diffuse outwards. This diffusion-controlled combustion process provides the weakest known flames and provides a means to study the limits of lean combustion. This is possible only in a microgravity environment, where buoyant



All the combustion in a flame ball takes place in a razor-thin reaction zone that depends on diffusion to keep the ball alive. Such a fragile balance is impossible on Earth.

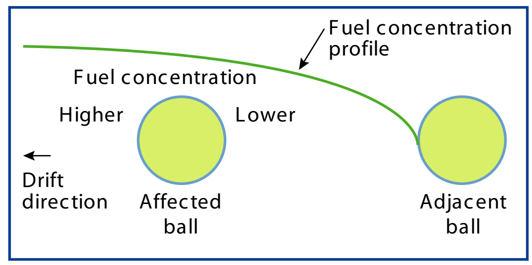
SOFBALL–2 Hardware

SOFBALL–2 experiments will be conducted inside the Combustion Module-2 (CM–2). CM–2 includes one rack that holds the Fluid Supply Package and video support equipment and a double rack that holds the Experiment Package, computer, and mechanical support equipment.

The Experiment Package is an aluminum combustion chamber with diagnostic equipment. Six fused-silica windows let external diagnostic instruments view and measure events inside the chamber. Diagnostic instruments include color and image-intensified cameras, and a gas chromatograph to measure combustion product composition.

The SOFBALL–2 Experiment Mounting Structure (EMS)—which includes experiment-specific diagnostic equipment—is cylindrical and about 62 cm long and 40 cm in diameter (24.4 by 15.7 in.), and weighs approximately 39 kg (87 lb). The main components are the spark igniter; temperature sensors (arranged as a rake of six thin thermocouple wires); two pairs of radiometers; a mixing fan; and volume compensators to reduce the amount of gas needed for each experiment.

A NASA engineer inspecting the EMS in the CM–2.



Scientists learned during SOFBALL–1 that flame balls drift away from each other at a decreasing rate, indicating that they move into areas of greater fuel concentration.

Fields Affected by SOFBALL Results

Combustion physics: Study the simplest interaction of chemistry and transport.

Spacecraft design: Systems that handle hydrogen or biological products (food, waste, and lab animals) that produce hydrogen and other combustible gases.

Automotive engineering: Design of lean-burning engines using pure hydrogen or using hydrocarbon fuels in which hydrogen combustion is a significant component.

SOFBALL–2 Operations

The flight crew will load the EMS into the combustion chamber and activate it. They will run the first three tests through the CM–2 laptop computer. The SOFBALL–2 science team on Earth will adjust conditions from one burn to the next, but the flight crew will initiate combustion, determine whether flame balls exist, adjust and monitor instruments, terminate the experiment, and initiate a reburn if needed. The flight crew can replace the spark igniter tips or thermocouple rake or manually adjust the spark settings, if necessary. The crew will also replace VCR cassettes and computer hard disk drives.

Key science measurements include flame ball size, brightness, temperature, radiant emission, lifetime, and combustion products.

Dr. Janice Voss, a mission specialist on the MSL–1 mission, services an EMS.

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For more information, please see the NASA Glenn Microgravity Combustion web site at
http://microgravity.grc.nasa.gov/combustion/

M–0723–13
Jun 02